УДК 691.32.008.6

ADVANCEMENT IN PILE FOUNDATION DESIGN IN KAZAKHSTAN CONSTRUCTION SITES AND CONTRIBUTION OF CENTRIFUGE TECHNOLOGY

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В статье приводятся общие аспекты концепции проектирования свайных фундаментов в строительных площадках Казахстана. Упомянуты такие современные технологии устройства свай, как CFA и DDS, используемые в Казахстане. В статье также представлены сравнения существующих результатов полевых испытаний свай с результатами таких современных методов испытания свай, как RLT и Центрифугой.

This paper presents the general aspects in Kazakhstan pile foundation design concept. Also such a modern pile technologies as CFA and DDS used in Kazakhstan are mentioned. The paper illustrates comparisons between the existing field pile test results with the results of advanced technologies such as RLT and Centrifuge becoming more applicable. The quality control methods such as PIT and geomonitoring of pile foundations are also noted in this paper.

More and more unique megaprojects have been realized and not a few projects are under construction, especially in the new capital of Kazakhstan – Astana (Figure 1). One of the stands out project is the housing estate “Abu-Dabi Plaza” which started on 1 July 2011 in Astana. The project of housing estate was designed by famous architect Norman Foster.

By preliminary evaluation, the cost of project exceeds 1.5 billion US dollars. This will be the highest building in Central Asia and ranked 14th in the world. "Abu-Dabi Plaza" - a complex from several towers, united around the main building with a height 382 meters - 88 floors (Figure 1). The high rates of construction and appearance of high-rise buildings led to a wide use of pile foundations. Modern construction puts modern requirements in front of engineers and designers, and so instead of traditional decisions it came to the use of new economically and ecologically efficient advanced technologies such as CFA (continuous flight auger), DDS (drilling displacement system).

Fig. 1. Megaprojects of Kazakhstan

An existing Kazakhstan standard documentation of pile design is out of date and does not meet the requirements of modern engineering. The standard needs to be revised. Nowadays, conception of pile foundation design [3] is in the process of modernization, as presented in Figure 2.

Design of pile foundation includes two critical stages of analysis: bearing capacity and settlement analysis. The preliminary design is performed based on the engineering and geological investigation of construction site. Accuracy of pile design generally depends on the accuracy of data presented in geological report. Final pile design project is corrected after approval by field tests.

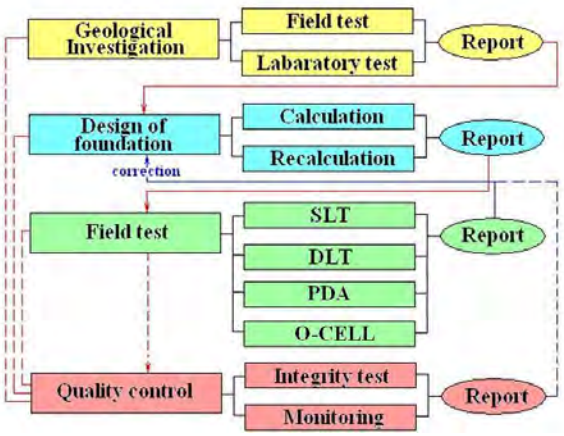

Fig.2. Pile foundation design concept

The classically bearing capacity is subdivided into two constituents: shaft and tip resistance. In Kazakhstan`s Standard the classical equation was modified and presented by following equation [1]:

$$F_d = \gamma_c(\gamma_{cR} RA + u\sum \gamma_{cf} f_i h_i) \quad (1)$$

where γ_c = safety factor; γ_{cR} and γ_{cf} = coefficients of soil work condition under the pile tip and around the pile, respectively.

Unfortunately, existing Kazakhstan Standards do not take into account soil compaction under the high concrete pressure in case of CFA technology and soil displacement without excavation in case of DDS technology that lead to reduction of settlement and increase in bearing capacities of pile foundation. Therefore it had been suggested to use following coefficients of soil working condition as presented in Table 1.

Table 1

Suggested coefficient of soil works for DDS and CFA piles

Type of pile	γ_{cR}	γ_{cf}
Driving Pile	1,0	1,0
Boring Pile	0,7-1,0	0,7
DDS (FDP) Pile	1,3	1,0
CFA Pile	1,0	1,0

As for SLT and DLT, they both are practiced in Kazakhstan construction. According to experience on construction sites of Astana, some difference exists between SLT and DLT results. Moreover, results of bearing capacity of pile depend on type of hammer. Thus, DLT results obtained by using hydro-hammer are more approximate to the SLT results, namely more reliable than results obtained by using diesel hammer [2]. The safety factor as defined by comparative analysis of many DLT and SLT data is presented in Figure 3.

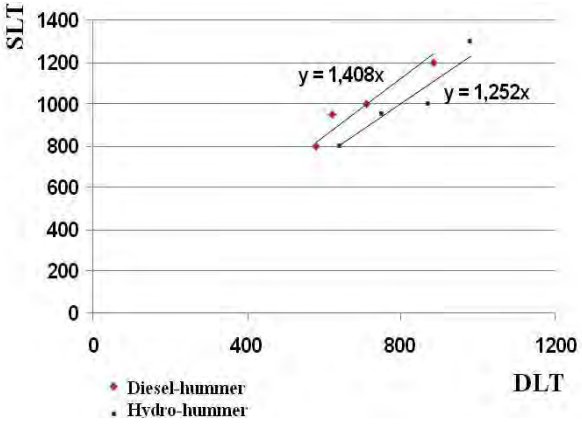

Fig. 3. Comparison SLT and DLT

From aforementioned it follows that SLT and DLT both have disadvantages. SLT required a lot of time, works and cost. Prescribed by Standard quantity of required SLT is not enough to adequately realize soil condition of construction site (2 SLT for 200 piles only). DLT is much faster but is not so reliable and is applicable to driving piles only.

Today, in process of adaption into Kazakhstan practice is an alternative load test method which precluded disadvantages of both SLT and DLT – Rapid Load Test (RLT). RLT allow performing up to 10 piles per day and much cost effective than SLT [4]. The comparison of SLT and RLT as obtained by Matsumoto are presented in Figure 5 that shows reliability of RLT.

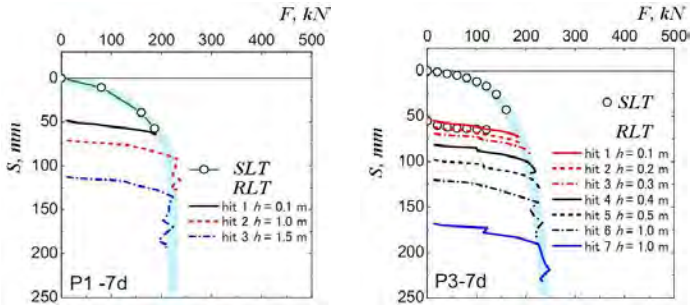

Fig. 4. Results of SLT and RLT

The one that is necessary to mention is the Centrifuge technology. Centrifuge modeling is currently the most reliable technique for using small scale tests of pile foundations to predict full scale conditions. Several pile model tests were performed using a balanced beam centrifuge (Figure 5) at Columbia University (New York, USA) to simulate and predict the behavior of real case. Obtained data was compared with the results of field pile tests, conducted by Ltd. «KGS» on the construction site of «Residential house» near the desert «Bestas» of Almaty region, Kazakhstan. The results of tests are presented in the Figure 6 [5].

Fig. 5. Columbia Centrifuge

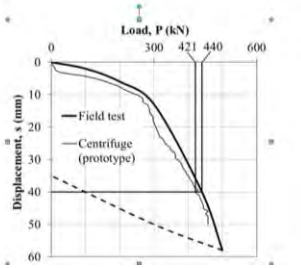

Fig. 6. Comparative results of Centrifuge and field pile tests

As for advancements in quality control of the pile foundations, it should be emphasized that the PIT (Pile Integrity Test) and geomonitoring are become more used in Kazakhstan.

PIT is one of the non-destructive methods of pile quality control. This method allows analyzing integrity control for all existing types of piles (boring, injection, driving and so on). PIT is based on wave propagation

theory in rigid body and is concerned with one of the modern quality control methods used world-wide. PIT allows detecting pile defects: approximate pile length, expansion and narrowing of pile cross section, modification of soil layers, heterogeneity of pile material, cracks in cross section of pile, extrinsic material in pile body. Advantages of PIT are as follows: portable device is easy to carry. One operator will be able to test over 100 piles per day, depends on site condition, pile head preparation and approach to the pile; minimum influence to the construction work on the site; significant defects may be detected in the beginning of the construction. PIT has some limitations: reflection of the bottom of pile sometimes has errors depending on soil condition; little deflection (less than 5 %) of pile cross section cannot be identified. According to Kazakhstan Standard requirements it is necessary to test 60% of boring piles and 50% of driving piles.

Geomonitoring for foundation settlement is one of the quality control methods that can be carried out during and after construction in exploitation period. Monitoring is indirect control of pile installation evaluation. The principle of this method is monitoring the settlement of special marks which are installed to interested points of construction. Monitoring starts from the beginning of construction and allows revealing defects of foundation installation.

CONCLUSIONS

Existing pile foundation Standards practiced in Kazakhstan are out-of-date and are in urgent need for modernization. This paper presented very short descriptions of coming changes to the concept of Kazakhstan pile foundation design.

Presented aspects of advanced pile technology design allow to making a more reliable prediction of bearing capacity and settlement of pile that has become very important for the preliminary design of pile foundation projects.

During designing of CFA pile of buildings and structures it needs to consider the volume of borehole expansion by the result of additional pressure, as well as over-expenditure of the concrete which is depend on soil conditions and length of pile. Significant differences between bearing capacities of DDS and casing boring piles show incomplete usage of DDS technology resources. The coefficient of shaft work of DDS pile was defined and equal from 1.2 to 1.3 depending on soil condition.

RLT allow performing up to 10 piles per day and much cost effective than SLT but cannot be used to full extent on construction sites of Kazakhstan due to absence of Standard.

The studies conducted earlier proved that the centrifuge is a good alternative approach for studying the work of the pile in the soil. The centrifuge model tests can predict the real behavior of soils or soil structures and determine their bearing capacities. It also may have significant economic effect compared with full-scale tests.

Pile integrity test is in the process of gaining official acceptance in Kazakhstan. PIT is a non-destructive method allowing make quality control of pile body whereupon of pile installation and even after many years of building exploitation.

Geomonitoring for foundation settlement is indirect control of pile quality evaluation method and has become more relevant, especially for high-rise building construction.

Application of advanced technologies of pile foundations installation led to a significant economic efficiency.

In implementing this Project in practice for the first time has been applied an integrated approach to the design, testing and quality control of pile foundations. This comprehensive approach is a guarantee of quality and efficient construction, which must be developed and applied in practice.

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